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# (12) UK Patent Application (19) GB (11) 2 371 578 (13) A

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GB 2351748 A

GB 2314866 A

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Online: WPI, EPODOC, PAJ

(54) Abstract Title

**Sand screen with active flow control**

(57) A tool for regulating the rate of fluid flow from an earth production zone comprises a flow control zone 23 through which fluid from the production zone is channelled. Preferably the flow control zone 23 is formed in an annular space between a central bore 11 and a surrounding production tubing 21. Within the flow control zone is a flow control device which selectively restricts the flow of fluid through it, and two sets of ports 24, 26, the first upstream of the device and the second downstream. Both sets of ports allow fluid to flow into the central bore 11 to carry the fluid to the surface and are selectively opened and closed. The control device comprises circumferentially placed stator columns 30 in the flow channel which can selectively interlock with sliding gate plugs 36, such that when they are engaged fluid cannot flow past, and the first set of ports 24 are open. Disengagement of the stator columns 30 and gate plugs 36 simultaneously closes the first set of ports 24 and allows fluid to flow beyond the stator columns. Downstream the fluid encounters a helically wound wall 28 which acts to reduce the fluid flow rate, before passing through the second set of ports 26 into the central bore 11. In an intermediate position both sets of ports are closed. In alternative embodiments the ports are opened and closes by electrically actuated solenoid valves or valves controlled by shape memory alloy, which reacts to the temperature of the fluid.

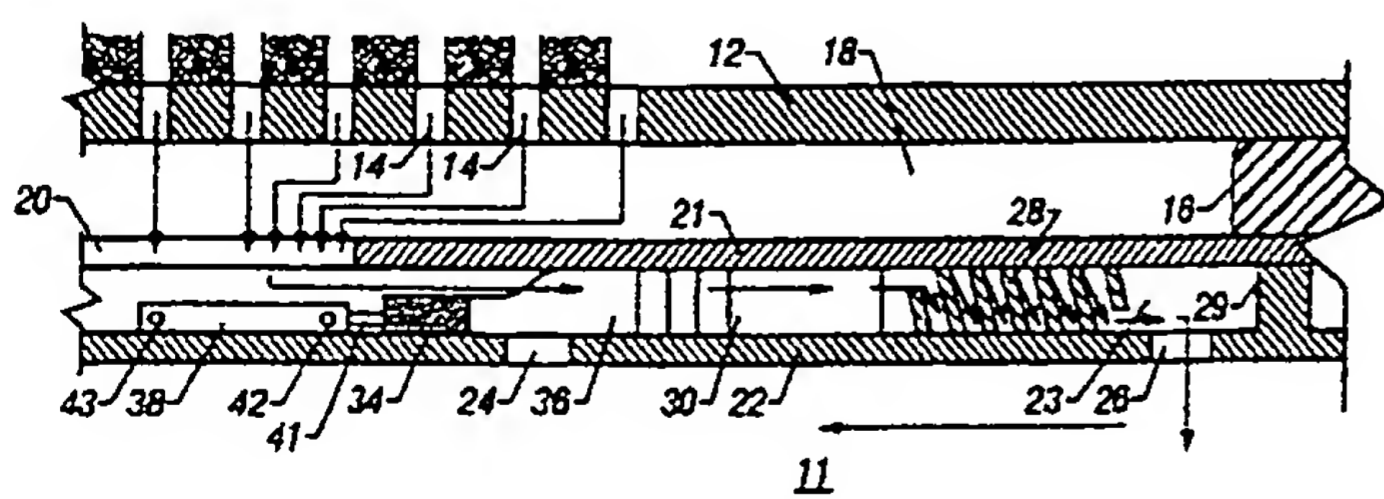


FIG. 2

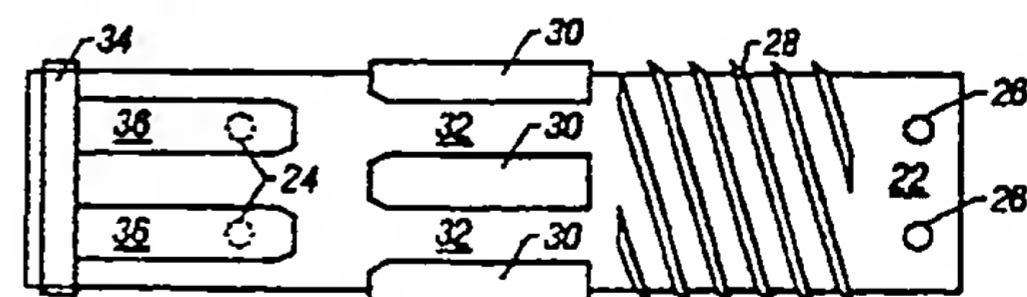


FIG. 5

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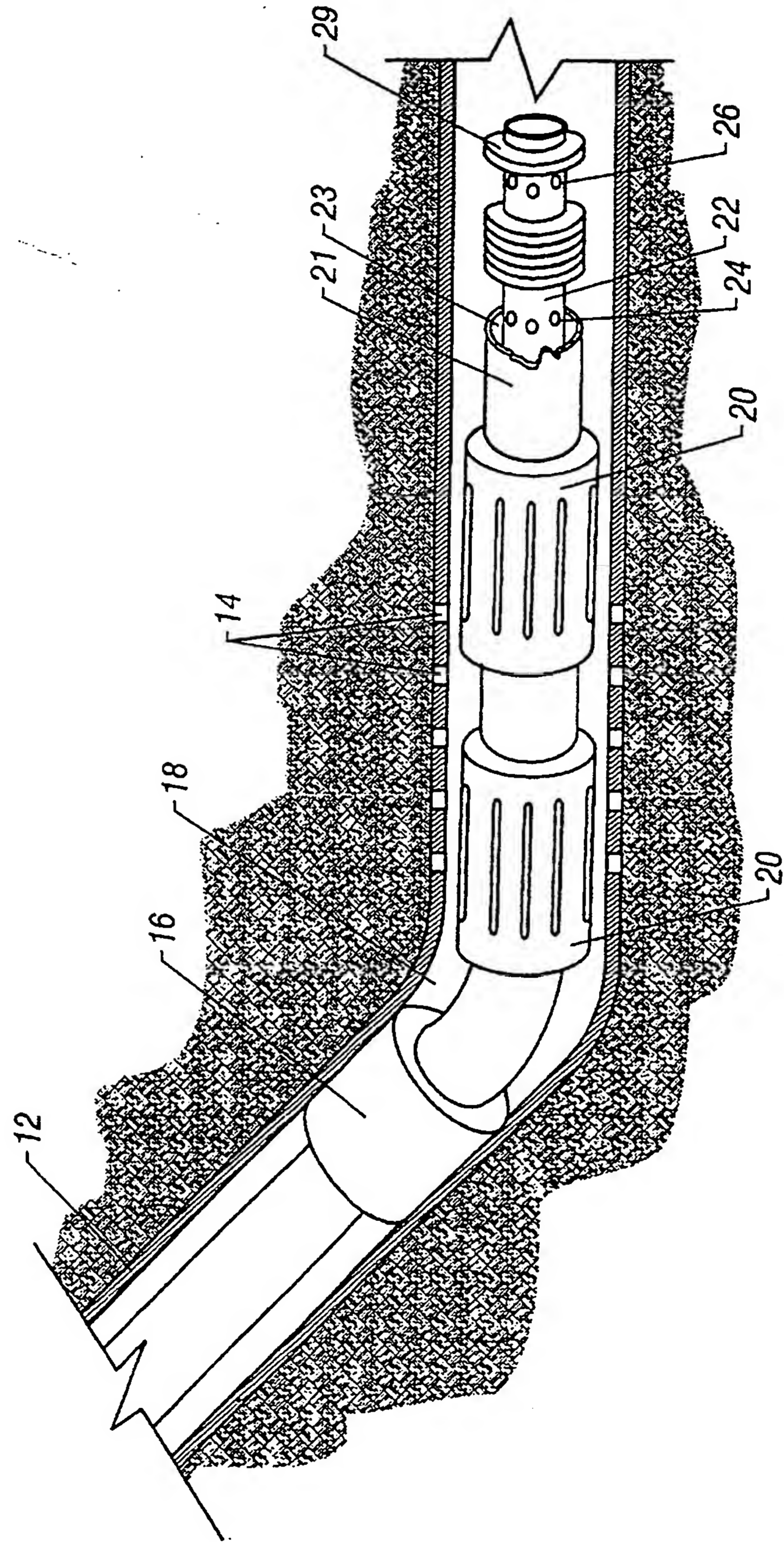


FIG. 1

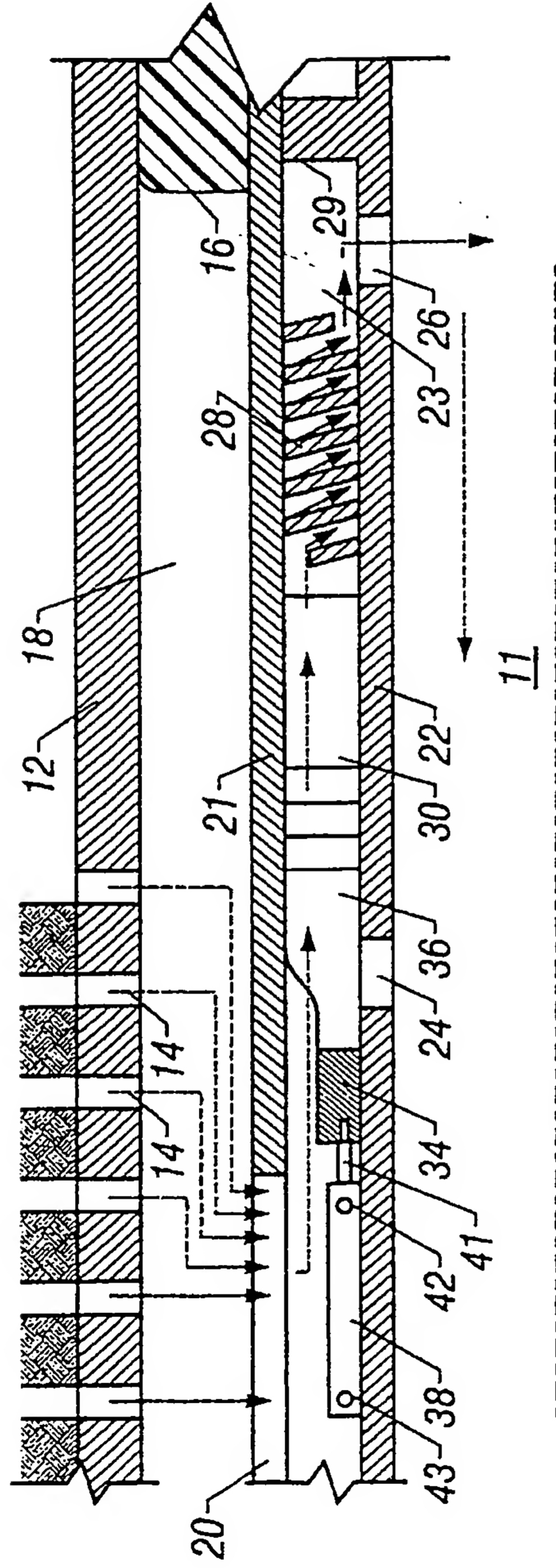


FIG. 2

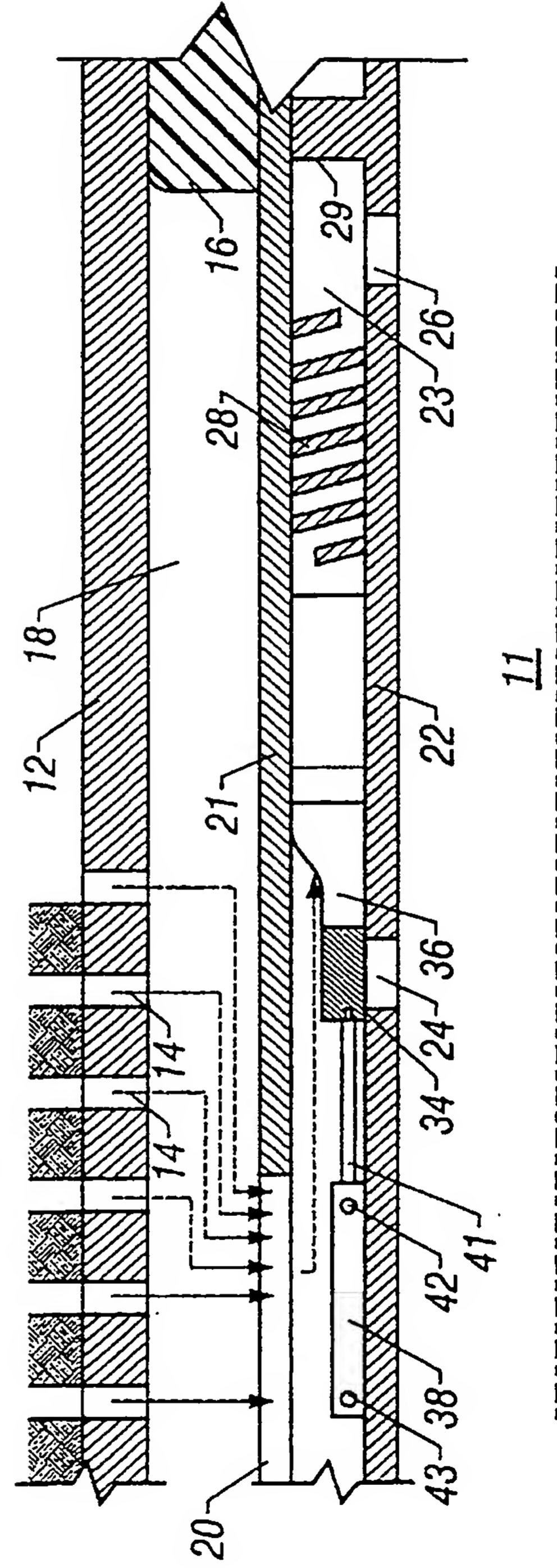


FIG. 3

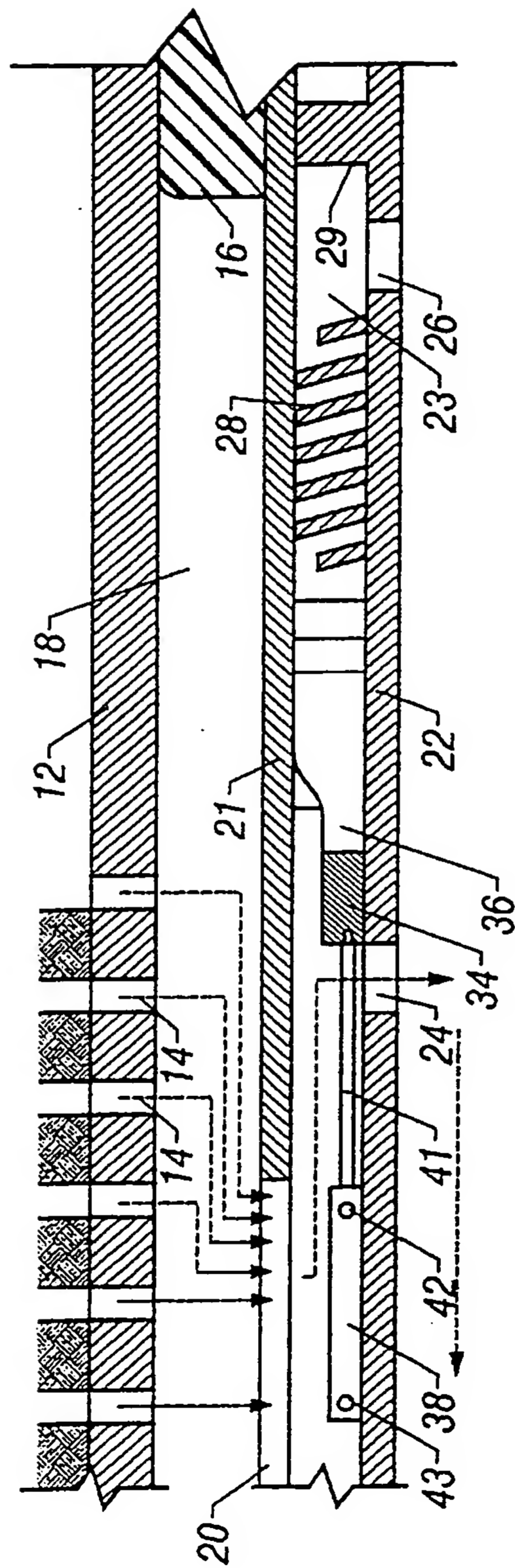


FIG. 4

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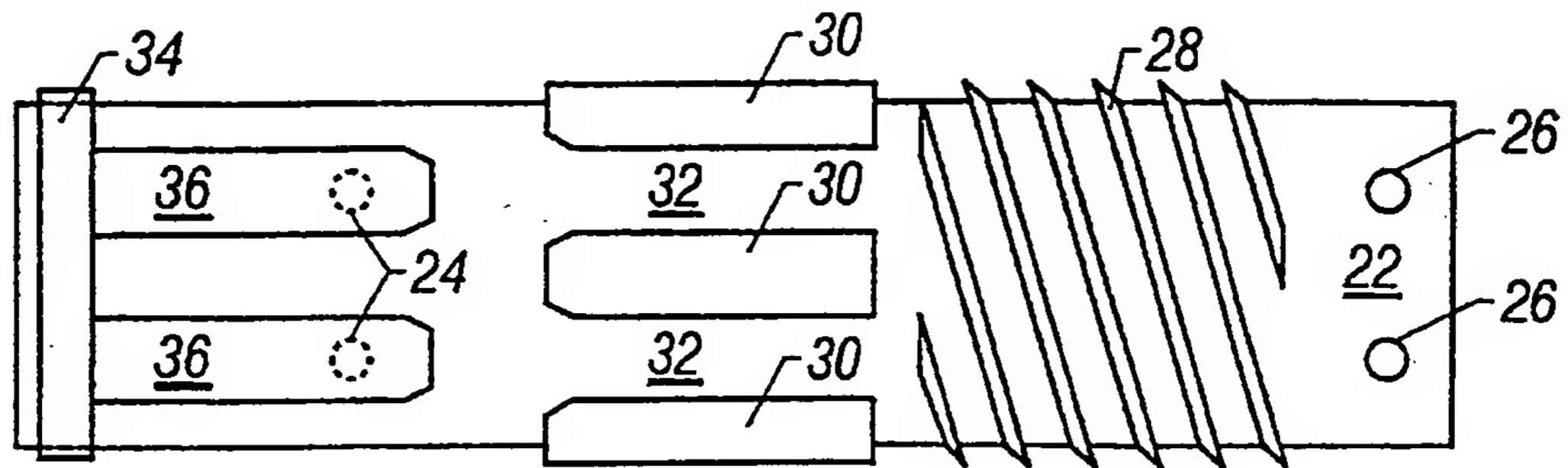


FIG. 5

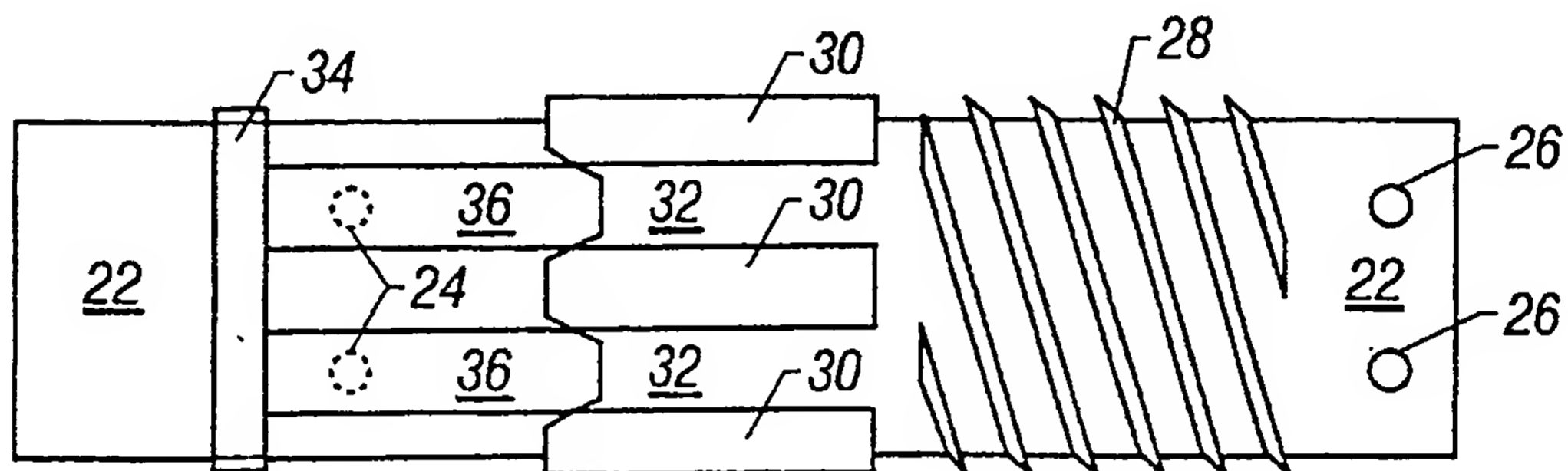


FIG. 6

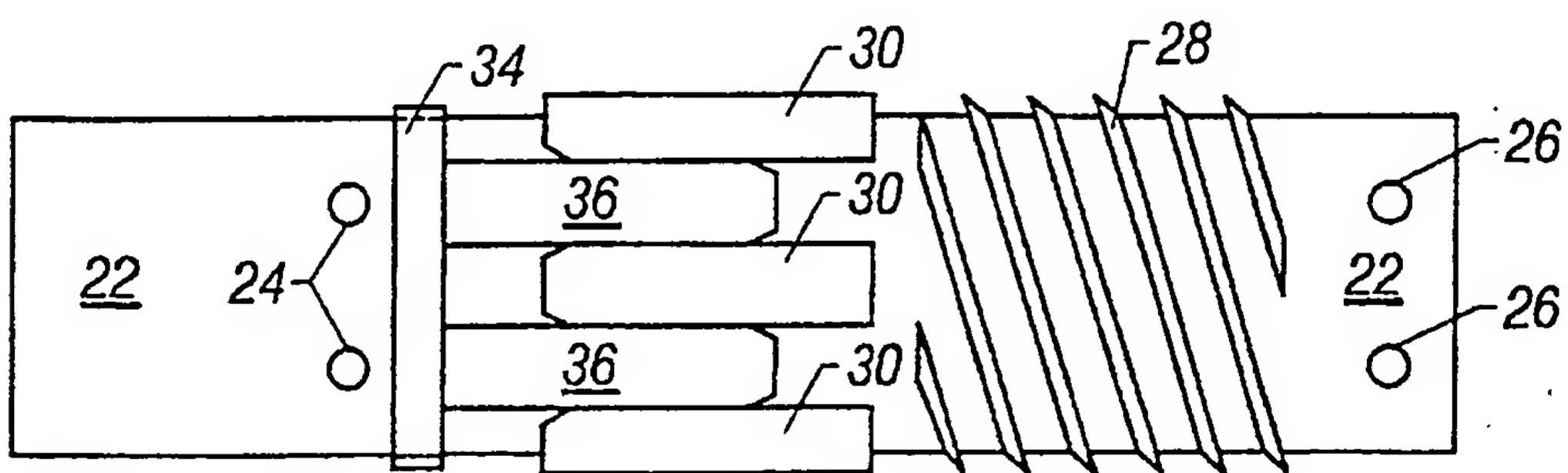


FIG. 7

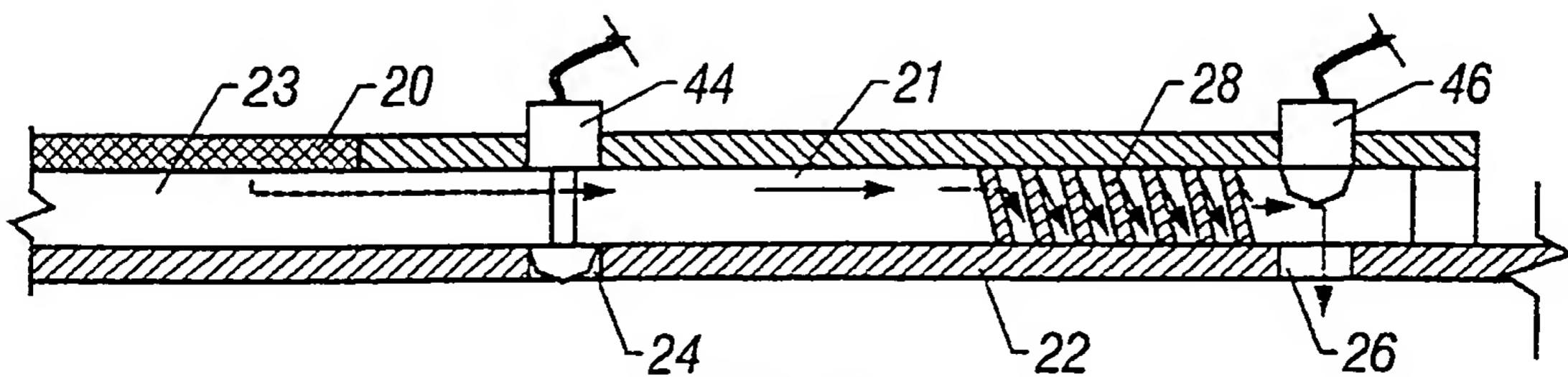


FIG. 8

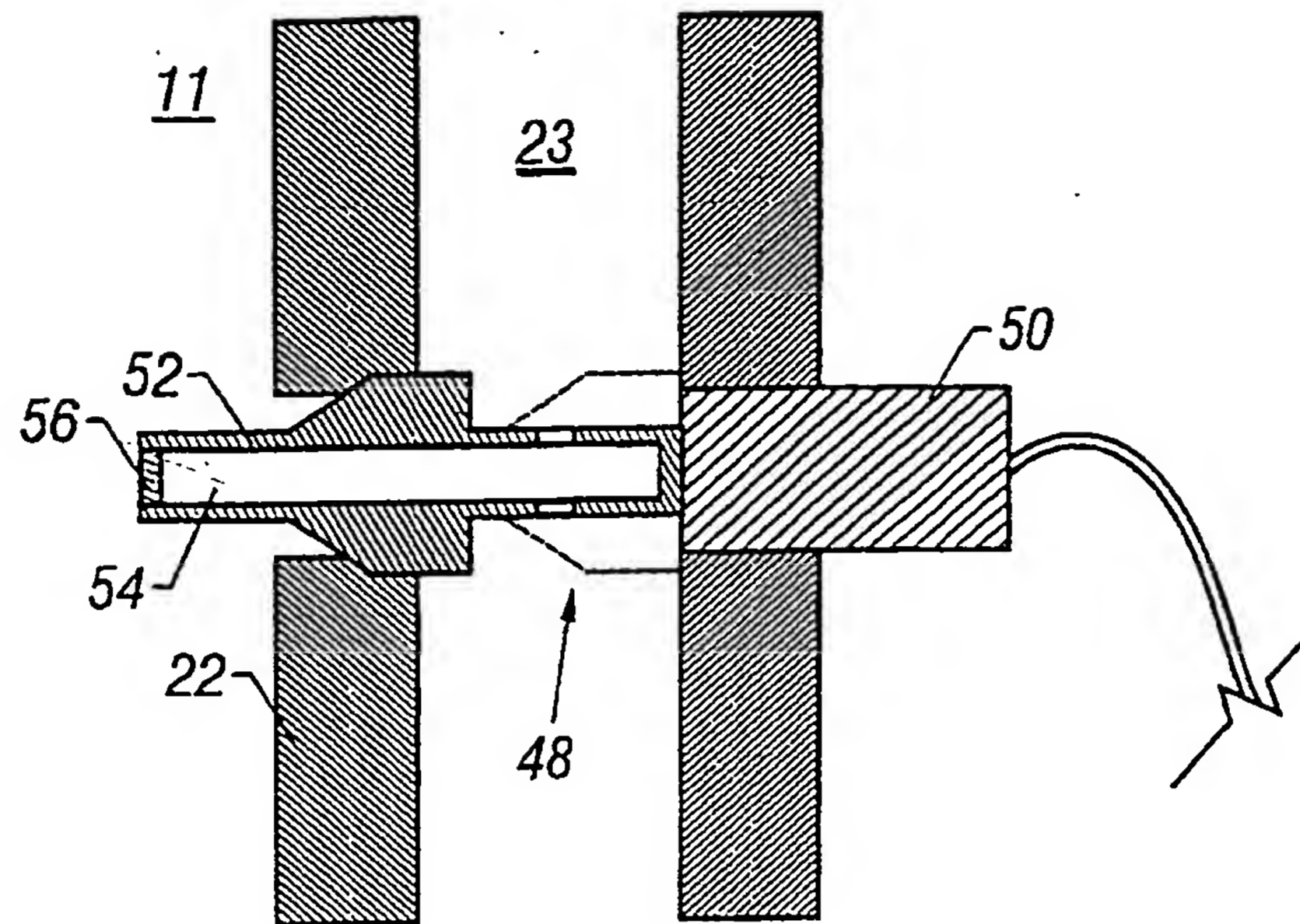


FIG. 9A

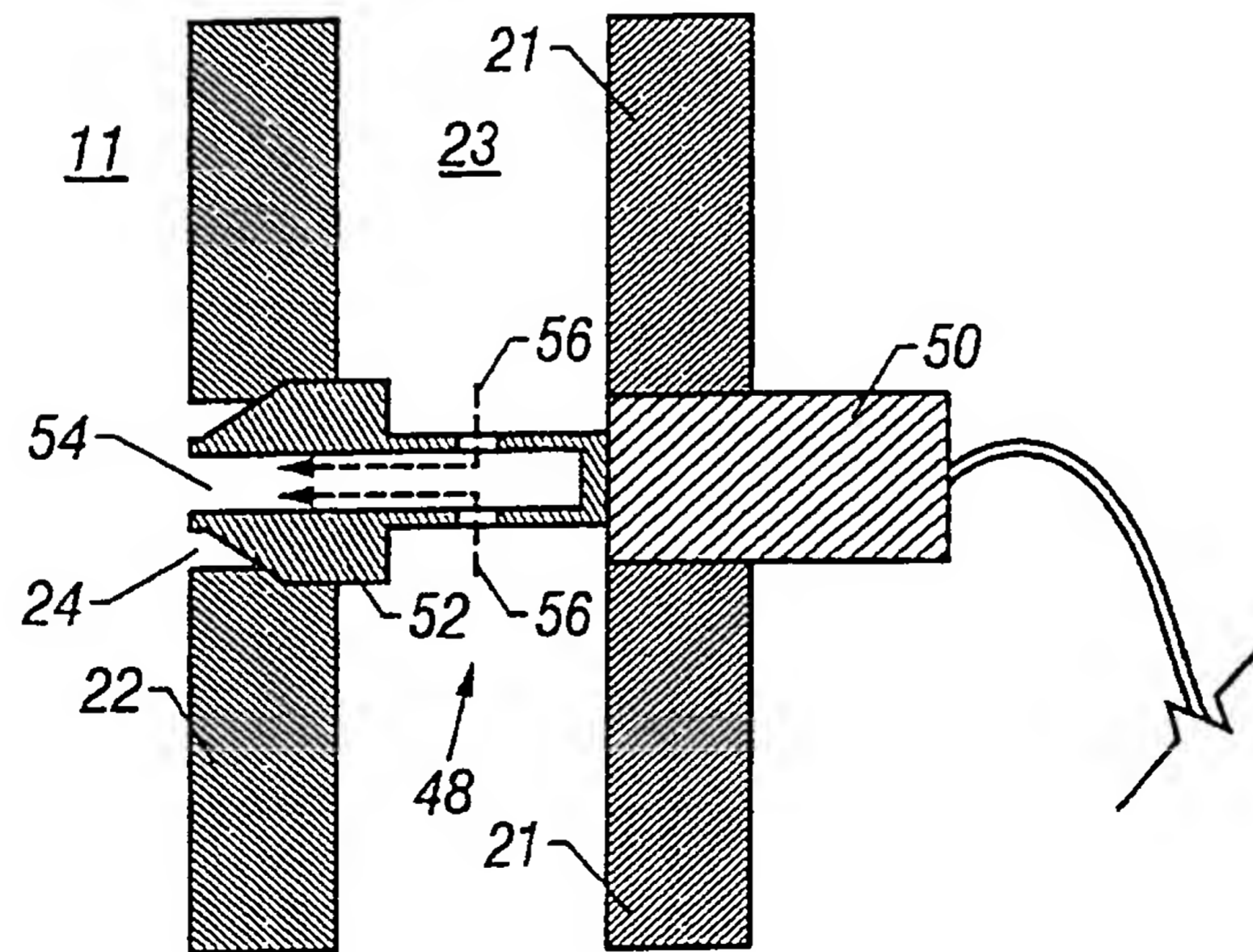


FIG. 9B

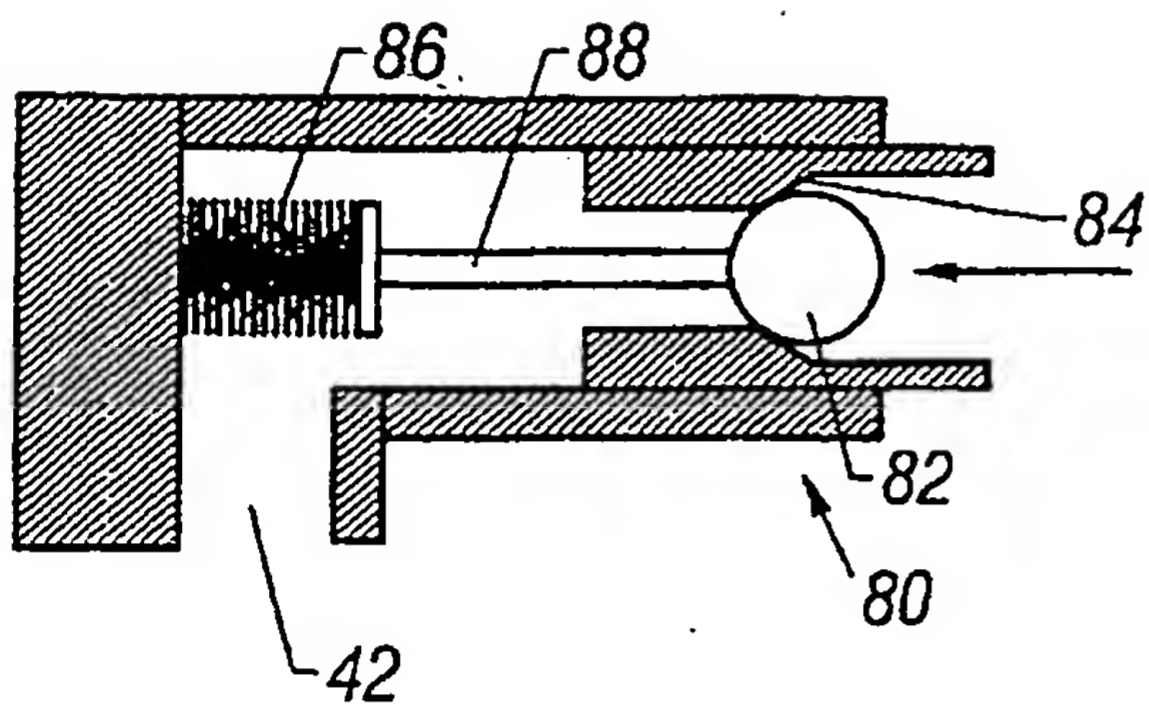


FIG. 10A

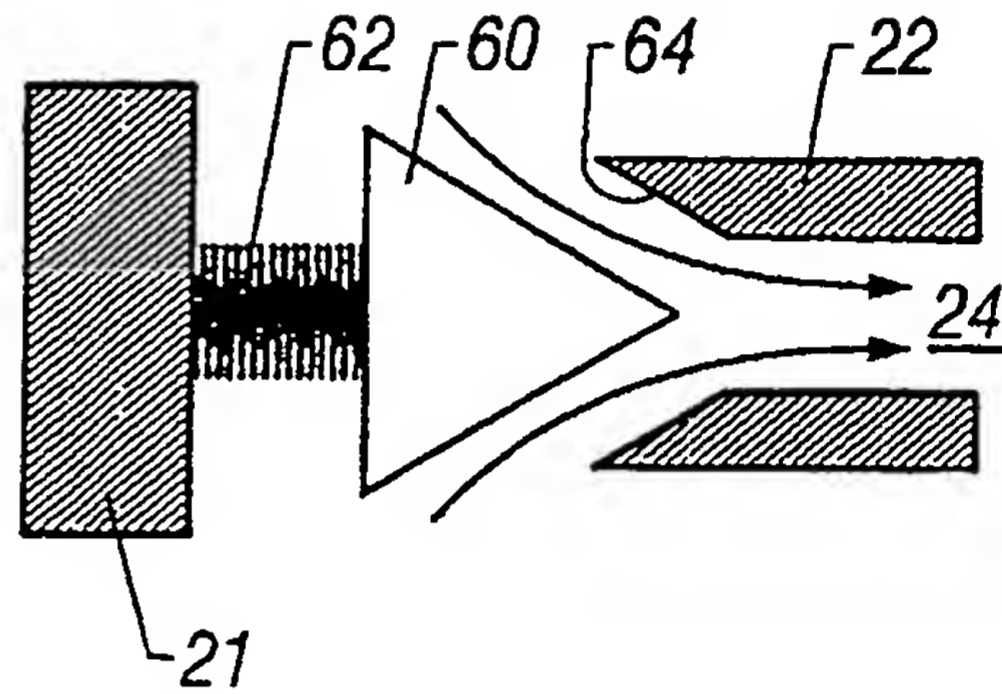


FIG. 11A

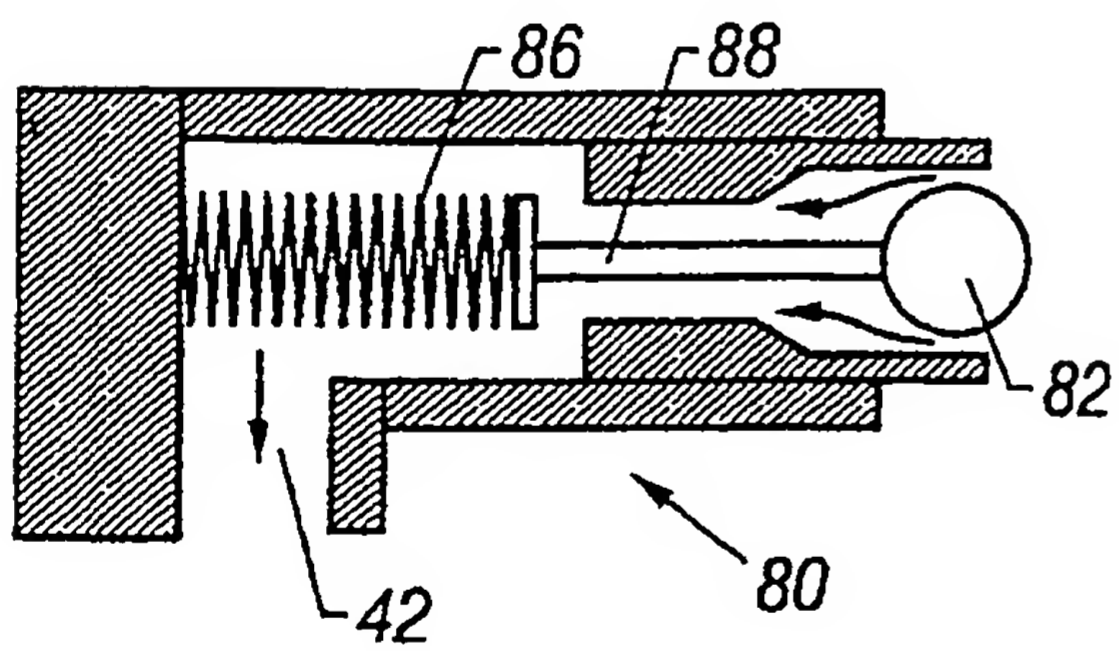


FIG. 10B

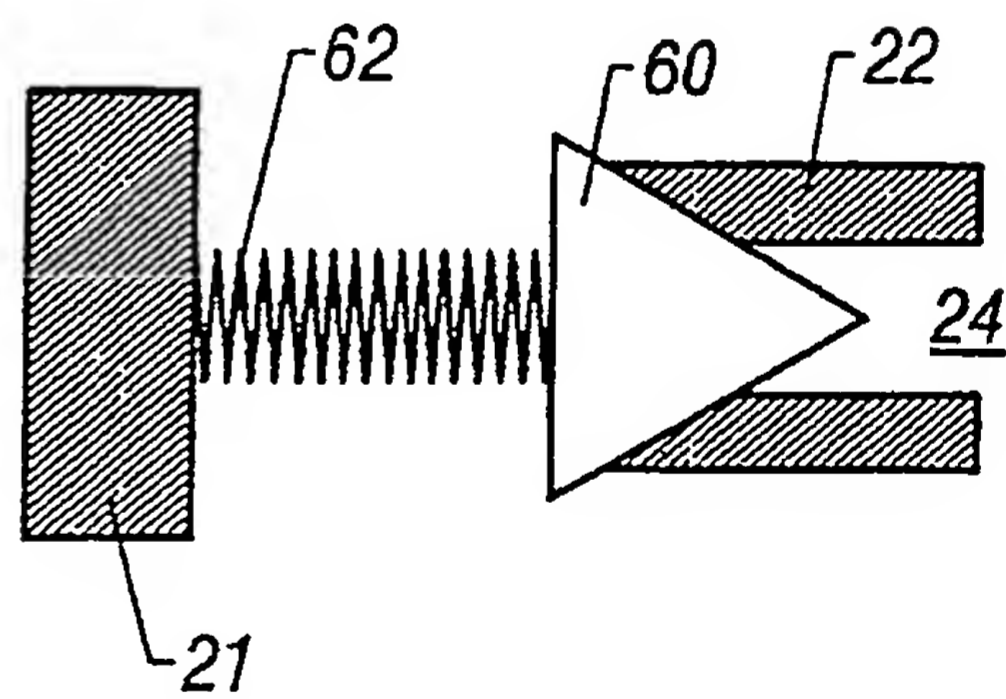


FIG. 11B

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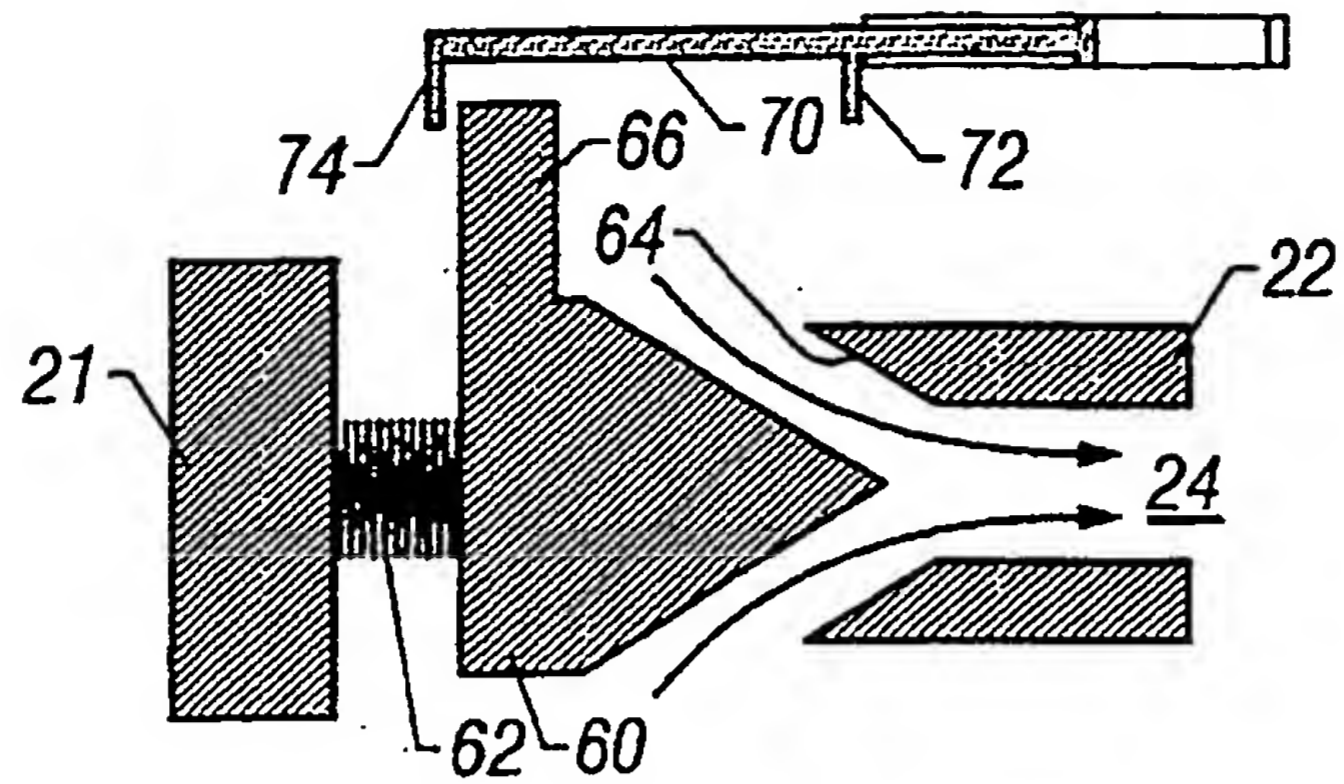


FIG. 12A

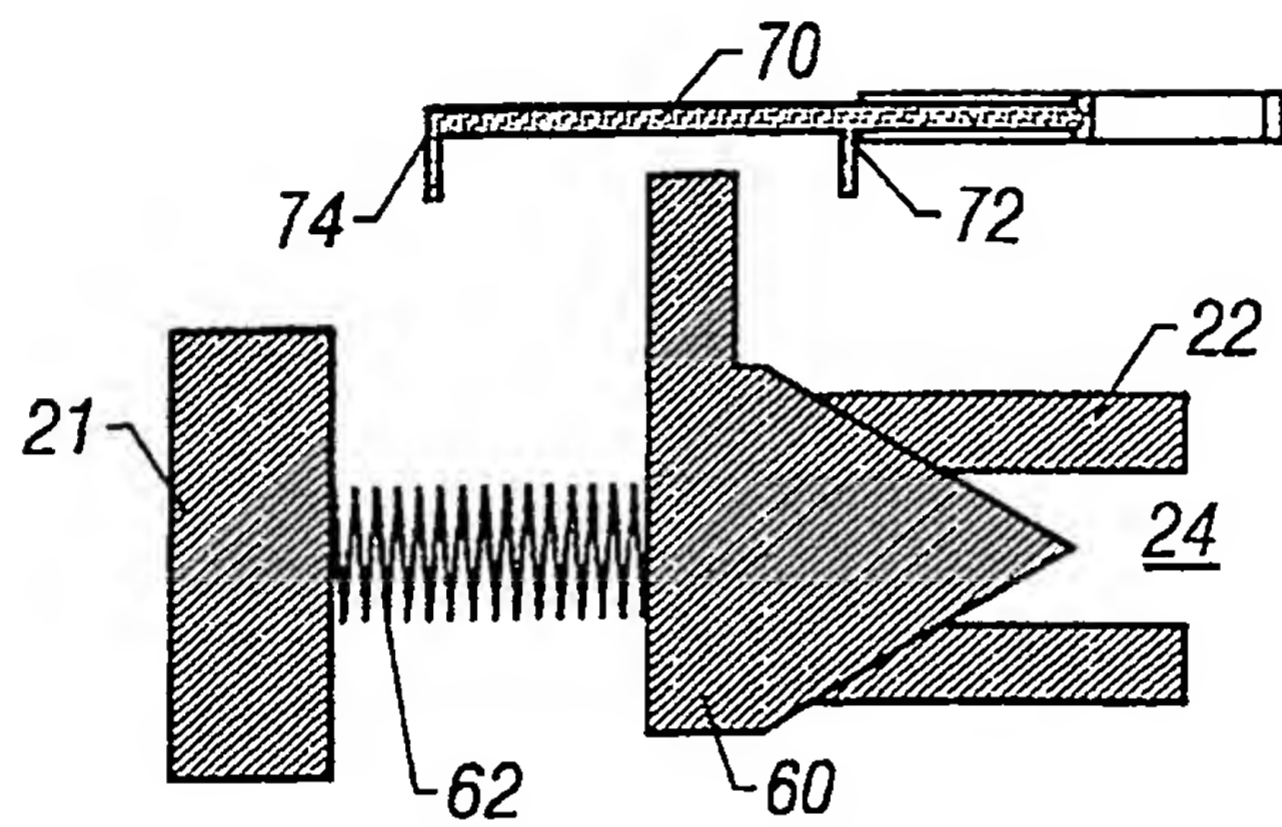


FIG. 12B

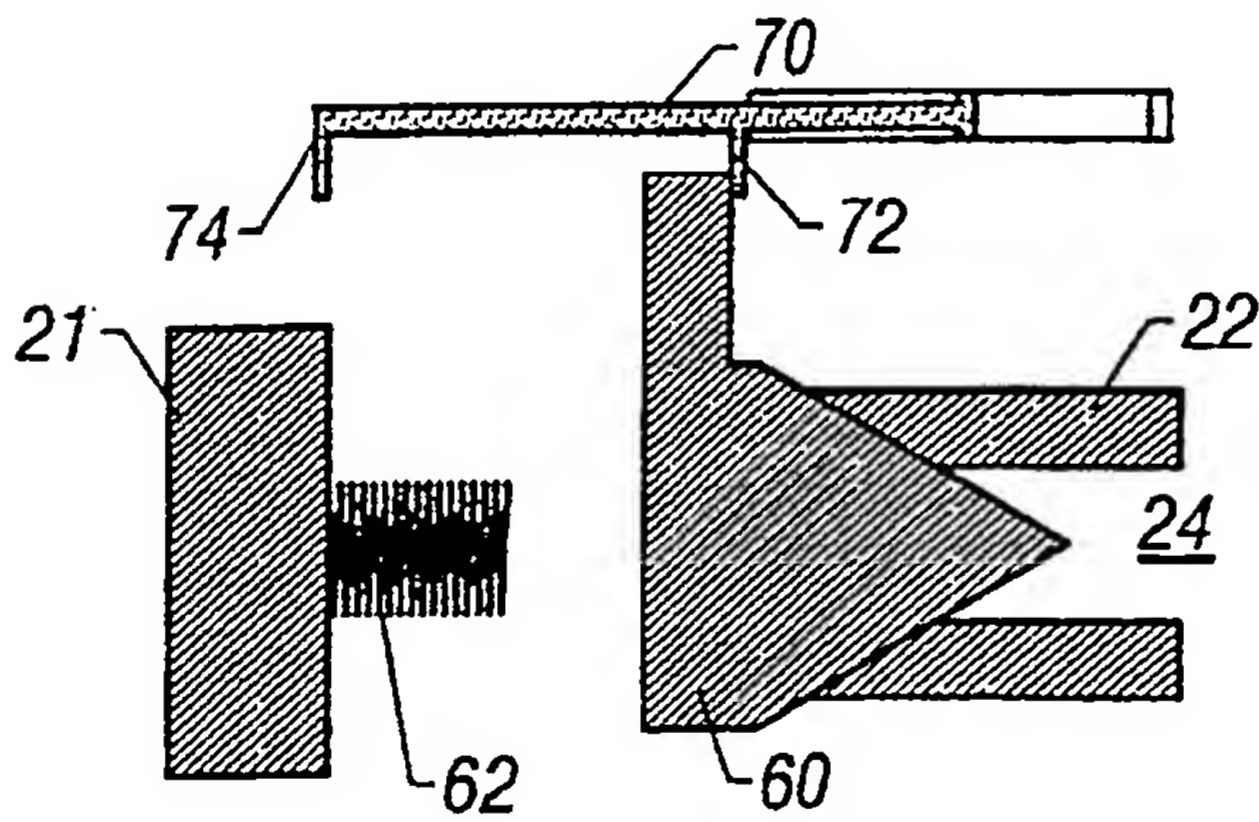


FIG. 12C

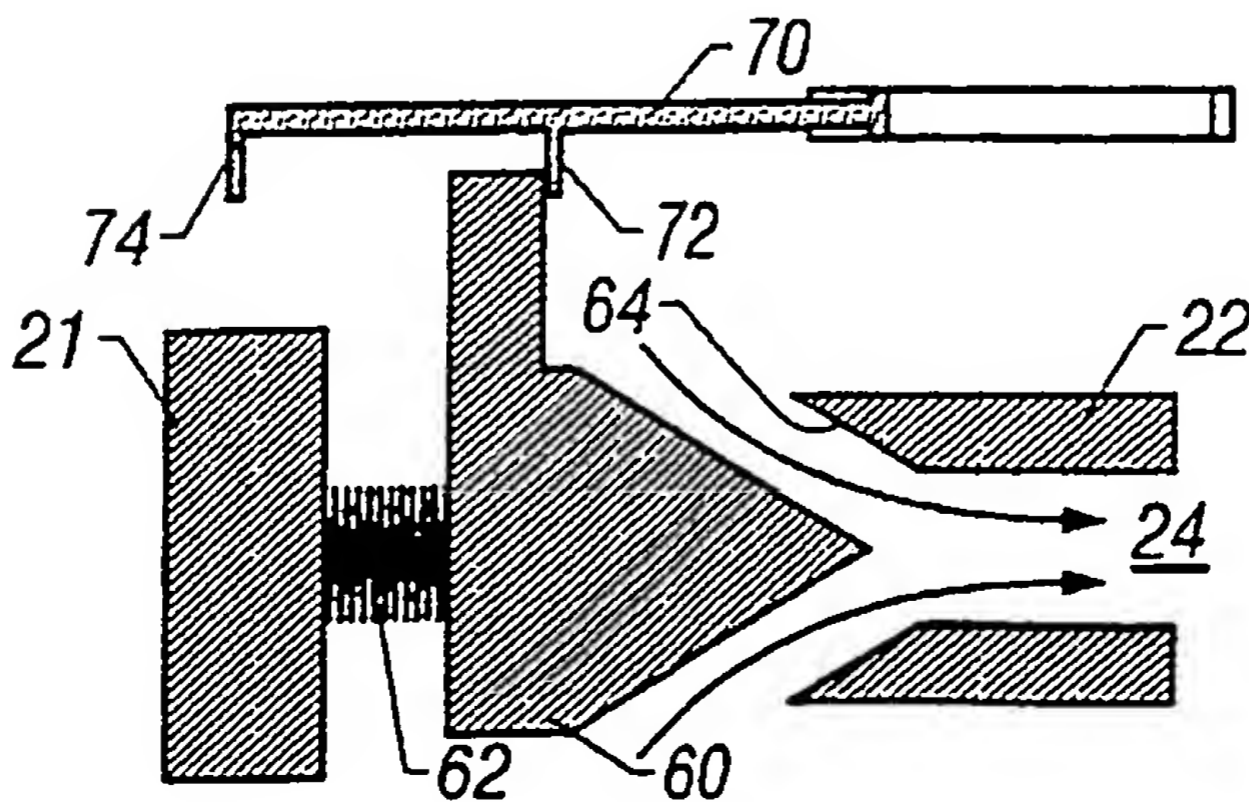


FIG. 12D

## 1 SAND SCREEN WITH ACTIVE FLOW CONTROL

2

3 BACKGROUND OF THE INVENTION4 FIELD OF THE INVENTION

5 The present invention relates to the art of well  
6 completion methods and equipment for the production  
7 of hydrocarbon fluids. More particularly, the  
8 invention relates to methods and apparatus for  
9 downhole regulation of hydrocarbon fluid production  
10 rates.

11

12 DESCRIPTION OF RELATED ART

13 Bottom hole well tools are exposed to extremely  
14 abrasive operating conditions. As hydrocarbon fluid  
15 is released from the naturally occurring in situ  
16 formation, sand, rock and other abrasive particles  
17 are drawn with it. In deeper wells where the in  
18 situ pressures are extremely high, the production  
19 pressure drop between the formation and the flow  
20 bore of the production tube is correspondingly high.  
21 Such high pressure differentials in the presence of  
22 a highly abrasive fluid rapidly erodes the  
23 production control tools. Fluid velocity through  
24 and over the tool surfaces, elements and apertures  
25 is an exponential function of the pressure  
26 differential drive. Hence, high pressure  
27 differentials translate to high fluid velocities.  
28 High velocity fluids entrained with abrasives  
29 translates to high rates of erosion, wear and  
30 failure.

31

1 Earth formation pressures and fluid production are  
2 not, however, fixed properties. Both of these  
3 properties change over time. Moreover, the changes  
4 are not necessarily linear or in predictable  
5 directions. The changes may be abrupt, irregular  
6 and/or fluctuating. In cases of an elongated  
7 production zone, often horizontal, the production  
8 properties may change in one section of the  
9 producing zone differently than those in another  
10 section of the same producing zone.

11

12 Although downhole tools for limiting the production  
13 rate of a production zone are known to the prior  
14 art, such tools have a fixed configuration.

15 Production flow rate adjustments are usually made at  
16 the surface. Downhole flow rate adjustment is  
17 accomplished by removing the production tools from  
18 the well bore and replacing a first fixed flow rate  
19 tool with a second fixed flow rate tool of different  
20 capacity.

21

22 It is, therefore, an object of the present invention  
23 to provide active flow control, from the surface,  
24 over production from gravel pack installations  
25 through sand control screens down to an individual  
26 screen.

27

28 Another object of the invention is provision of  
29 means to regulate the inflow of fluids from a long,  
30 horizontal petroleum reservoir to maximize  
31 production.

32

1 Also an object of the present invention is provision  
2 of means to terminate production flow from a  
3 production screen or to divert flow from one screen  
4 to another within the screen assembly.

5  
6 A further object of the invention is provision of  
7 means to adjust the production flow rate of a well.

8  
9 SUMMARY OF THE INVENTION

10

11 These and other objects of the invention are served  
12 by a tool that is associated with a production sand  
13 screen to channel the screened production flow  
14 through a flow control zone. Within the flow  
15 control zone is a static flow control device that  
16 reduces the fluid pressure differential over an  
17 extended length of flow restrictive channel. At  
18 either end of the flow control device are transverse  
19 flow apertures disposed between the flow control  
20 zone and the internal flow bore of the primary  
21 production tube.

22

23 The apertures are flow controlled as either opened  
24 or closed completely. This operational set allows  
25 three flow states. When the apertures upstream of  
26 the flow control device are closed and those  
27 downstream are open, all production flow from the  
28 associated screen must pass through the flow control  
29 device. In doing so, the flow stream is required to  
30 follow a long, helical path. Traversal of the flow  
31 control device dissipates the pressure of state  
32 within the fluid thereby reducing the pressure

1 differential across the production tool. The energy  
2 potential of the pressure is converted to heat.

3

4 When apertures upstream of the flow control device  
5 are open and those downstream are closed, production  
6 flow is shunted directly from the flow control zone  
7 into the internal flow bore of the primary  
8 production tube. This operational state permits the  
9 particular tool to run "open choke" but not  
10 necessarily all tools in the formation.

11

12 The third flow state closes both apertures to  
13 terminate all production flow from the associated  
14 screen.

15

16 A preferred embodiment of the invention provides a  
17 cylindrical tool mandrel within the internal bore of  
18 a production tube that forms an annular flow channel  
19 along the tube axis. Axially displaced from the  
20 screen inflow area, is a circumferential band of  
21 longitudinal stator columns that span radially  
22 across the flow channel annulus to funnel the  
23 annulus flow through gates between the stator  
24 columns. Further displaced axially along the flow  
25 channel annulus is a helically wound wall that also  
26 spans radially across the flow channel annulus.  
27 This helically wound wall is one embodiment of a  
28 static flow control device.

29

30 Two sets of flow apertures through the mandrel wall  
31 section link the annular flow channel with the  
32 internal bore of the production tube. A first

1 aperture set is positioned axially displaced from  
2 the static flow control device opposite from the  
3 band of stator columns. A second aperture set is  
4 positioned axially displaced from the band of stator  
5 columns opposite from the flow control device. An  
6 axially slideable ring substantially encompasses the  
7 mandrel at an axial location adjacent to the stator  
8 columns opposite from the static flow control  
9 device. The ring is axially displaced by one or  
10 more hydraulic cylinders. From one annular edge of  
11 the ring projects a number of gate plugs. The  
12 number of plugs corresponds to the number of gates.  
13 The gate plugs overlies the second set of flow  
14 apertures at all positions of axial displacement but  
15 one.

16 At a first, axially stroked extreme position of the  
17 ring, the second flow aperture set is open to  
18 facilitate direct and unrestricted flow of  
19 production flow from the channel annulus into the  
20 internal bore.

21  
22 At an intermediate axial position of the ring, the  
23 plugs close the gates between the stator columns  
24 thereby blocking flow to the first flow aperture  
25 set. Also at this intermediate setting, the gates  
26 block flow through the second set of apertures by  
27 their lapped, overlay location. Consequently, at  
28 the intermediate setting, no flow from the channel  
29 annulus is admitted into the inner bore.

30  
31 At a second axial extreme position, the plugs are  
32 withdrawn from the gates to allow flow through the

1 static flow control device and into the first set of  
2 flow apertures. However, at the second axial  
3 extreme position the plugs continue to block flow  
4 through the second set of flow apertures.  
5 Consequently, the flow stream is required to  
6 traverse the static flow control device to reach the  
7 inner production tube bore.

8

9 BRIEF DESCRIPTION OF THE DRAWINGS

10

11 The advantages and further aspects of the invention  
12 will be readily appreciated by those of ordinary  
13 skill in the art as the same becomes better  
14 understood by reference to the following detailed  
15 description when considered in conjunction with the  
16 accompanying drawings in which like reference  
17 characters designate like or similar elements  
18 through the several figures. Briefly:

19 FIG. 1 is an environmental schematic of the  
20 invention;

21 FIG. 2 is a cross-sectional view of the invention in  
22 a flow restrictive setting;

23 FIG. 3 is a cross-sectional view of the invention in  
24 a flow obstructing setting;

25 FIG. 4 is a cross-sectional view of the invention in  
26 a free-flow setting;

27 FIG. 5 is a plan view of the invention mandrel in  
28 the restrictive flow setting;

29 FIG. 6 is a plan view of the invention mandrel in a  
30 flow obstructing setting;

31 FIG. 7 is a plan view of the invention mandrel in a  
32 free-flow setting;

1 FIG. 8 is a solenoid valve controlled embodiment of  
2 the invention;  
3 FIG. 9A is a cross-sectional view of a special case  
4 solenoid valve pintle in a normal operating mode;  
5 FIG. 9B is a cross-sectional view of a special case  
6 solenoid valve pintle in a normal operating mode;  
7 FIG. 10A is a hydraulic control schematic in the  
8 hydraulic fluid flow blocking mode due to production  
9 flow temperature;  
10 FIG. 10B is a hydraulic control schematic in the  
11 hydraulic fluid flow open mode due to production  
12 flow temperature;  
13 FIG. 11A is a production valve control system  
14 responsive to a shape memory alloy driver to open a  
15 production flow transfer aperture;  
16 FIG. 11B is a production valve control system  
17 responsive to a shape memory alloy driver to close a  
18 production flow transfer aperture; and,  
19 FIGS. 12A through 12D illustrate the operational  
20 sequence of an automatic, thermally controlled valve  
21 pintle.

22

23 DESCRIPTION OF THE PREFERRED EMBODIMENTS

24

25 With respect to the environmental schematic of FIG.  
26 1, a production tube 10 is positioned within a  
27 wellbore casing 12 to provide a continuous flow  
28 conduit to the surface for a flow of fluids  
29 extracted from a subterranean earth formation.  
30 Along a formation fluid production zone, the casing  
31 is perforated by apertures 14 for facilitation of  
32 formation fluid flow into an outer production

1 annulus 18 between the interior wall of the casing  
2 and the exterior wall of the production tube.  
3 Longitudinally, the production annulus 18 may be  
4 delimited by an outer packer 16.

5

6 Below the outer packer 16, the production tube 10  
7 includes one or more sand screens 20 linked by flow  
8 control housings 21. Internally of the screens and  
9 flow control housings is a flow control mandrel 22.  
10 A flow control annulus 23 is accommodated between  
11 the interior walls of the flow control housings 21  
12 and the exterior walls of the mandrel 22. The  
13 continuity of the flow control annulus 23 may be  
14 interrupted between sand screens 20 by an inner  
15 packer 29.

16

17 Referring now to the partial cross-section of FIG. 2  
18 and the schematic plan of FIG. 5, it is seen that  
19 the wall of mandrel 22 is penetrated by two  
20 circumferential sets of flow apertures 24 and 26.  
21 Between the apertures 24 and 26, the outer mandrel  
22 surface is profiled by surfaces that extend radially  
23 out to juxtaposition with the interior surface of  
24 the housing thereby substantially confining all  
25 fluid flow along the flow control annulus 23.

26

27 A first exterior profile on the flow control mandrel  
28 22 is a circumferential band of substantially  
29 uniformly spaced stator columns 30. Between the  
30 stator columns 30 are flow gates 32. A second  
31 exterior profile on the flow control mandrel 22 is a

1 static flow control device 28 comprising a helically  
2 wound channel between parallel walls.

3 Proximate of the first circumferential set of flow  
4 apertures 24 is a circumferential set of gate plugs  
5 36 extending from one edge of a base ring 34. The  
6 opposite base ring 34 edge is attached to one or  
7 more hydraulic, for example, struts 38.

8 Representatively, a strut 38 may comprise a cylinder  
9 40 secured to the surface of mandrel 22 and a piston  
10 rod 41 secured to the opposite edge of the base ring  
11 38. The rod 41 may be extended axially from the  
12 cylinder 40 to axially reposition the base ring 38  
13 and gate plugs 36 by manipulations of pressurized  
14 hydraulic fluid in one or two hydraulic fluid  
15 conduits 42 and 43. Extensions of the conduits 42  
16 and 43 to the surface enable these manipulations  
17 from the surface if required. Downhole hydraulic  
18 fluid power control may also be accomplished by  
19 numerous other means and methods known to the active  
20 practitioners of the art.

21

22 As may be observed from a comparison of FIGS. 5, 6  
23 and 7, the rod 41 is stroked to provide the base  
24 ring 38 and projecting gate plugs 36 an intermediate  
25 position (FIG. 6) between two extreme positions  
26 (FIGS. 5 and 7). At the FIG. 5 position, production  
27 flow may travel along the control annulus 23, around  
28 the gate plugs 36, through the gates 32 between  
29 stator columns 30, and along the helically wound  
30 flow channel of the static control device 38 into  
31 the apertures 26. From the apertures 26, the fluid  
32 enters the inner bore 11 of the production tube to

1 be lifted or driven by expanding gas to the surface.  
2 To be noted from FIG. 5 is the overlaid relationship  
3 of the apertures 24 by the gate plugs 36 thereby  
4 effectively blocking fluid flow into the apertures  
5 24.

6  
7 When the gate plugs 36 are shifted to the  
8 intermediate position shown by FIG. 6, the plugs 36  
9 fill the flow channel space 32 between the stator  
10 columns 30 thereby blocking flow into the static  
11 flow control device 28. Consequently, no flow  
12 reaches the apertures 26 for flow into the inner  
13 bore 11. Moreover, gate plugs 36 continue to  
14 overlies the aperture set 24 and block fluid flow  
15 therethrough.

16  
17 FIG. 7 illustrates the alternative extreme position  
18 whereat the gate plugs 36 enter the gates 32 fully  
19 thereby continuing the blockage of flow into the  
20 apertures 26. However, as the gate plugs 36 move  
21 deeper into the gates 32, the apertures 24 are  
22 uncovered. At this arrangement, only a minimum of  
23 flow resistance is imposed as the production flow  
24 stream finds its way to the surface.

25  
26 The alternative embodiment of the invention depicted  
27 by FIG. 8 controls the opening and closing of  
28 apertures 24 and 26 with electrically actuated  
29 solenoid valves 44 and 46. For unrestricted flow,  
30 valves 44 would be opened and valves 46 closed. For  
31 maximum flow resistance, Valves 44 would be closed  
32 and valves 46 opened to force the production flow

1 through the static flow restriction device 28. For  
2 zero flow, of course, both valves 44 and 46 are  
3 closed.

4  
5 As a permutation of the FIG. 8 embodiment, FIGS. 9A  
6 and 9B illustrate a solenoid valve 48 having an  
7 electrically energized winding 50 secured in the  
8 housing 21 for selectively translating a pintle 52  
9 into or out of a flow aperture 24 or 26.  
10 Distinctively, the pintle 52 is centrally hollow.  
11 The hollow core 54 of the pintle stem is closed by  
12 plug 58 at the end that penetrates into the inner  
13 flow bore 11. However, the hollow core is open to  
14 the control flow annulus 23 by apertures 56 when the  
15 pintle 52 is at the closed aperture 24 position. In  
16 the event of power or control failure of a nature  
17 that prevents a desired opening of a closed valve  
18 48, a restricted by-pass flow may be obtained by  
19 deployment of a shear dart from the surface along  
20 the inner bore 11 to mechanically break the end of  
21 the pintle stem and expose the hollow core 54.

22  
23 As the flow of the production fluid transfers energy  
24 to the flow control equipment, frictional heat is  
25 generated. Consequently, the equipment temperature  
26 bears a functional relationship to the production  
27 flow rate. Based on the fact that operating  
28 temperatures of flow control devices change as a  
29 function of flow rates, automated downhole control  
30 of such devices may be accomplished with valves that  
31 respond operationally to the temperature changes.  
32 FIGS. 11A and 11B illustrate one embodiment of this

1 principle wherein a valve pintle element 60 is  
2 operatively driven by a shape memory alloy 62 into  
3 cooperative engagement with a valve seat 64 to  
4 directly control production flow through an aperture  
5 24. FIG. 11A schematically illustrates the valve  
6 elements in a production flow condition wherein the  
7 flow rate through the flow aperture 24 is  
8 insufficient to generate heat at a rate that is  
9 sufficient to expand the shape memory alloy valve  
10 driver 62. In contrast, FIG. 11B schematically  
11 illustrates a non-flow condition wherein the shape  
12 memory alloy driver 62 has expanded due to excessive  
13 heating and pushed the pintle 60 into engagement  
14 with the aperture 24 seat 64.

15  
16 The invention embodiment of FIGS. 12A-12D modifies  
17 the foregoing control structure further with a  
18 mechanically controlled override. In this design,  
19 the valve pintle 60 includes, for example, an  
20 engagement tab 66 that cooperates with shift fingers  
21 72 and 74 that depend from a selectively stroked  
22 hydraulic strut. FIG. 12A schematically illustrates  
23 the production flow condition in which the shape  
24 memory alloy driver 62 is contracted and the pintle  
25 60 is withdrawn from the valve seat 64. The strut  
26 70 is at an intermediate position with the shift  
27 finger 74 in close proximity with the engagement tab  
28 66. FIG. 12B schematically illustrates a condition  
29 change wherein flow generated heat has expanded the  
30 alloy driver 62 and caused the pintle 60 to be  
31 translated into closure contact with the valve seat  
32 64.

1

2 Represented by FIG. 12C is a disfunction condition  
3 wherein the alloy driver 62 has cooled and  
4 contracted but the pintle 60 has not drawn away from  
5 the seat 64 to open the aperture 24. FIG. 12D  
6 schematically illustrates the override of the shape  
7 memory alloy 62 with an engagement of the pintle tab  
8 66 by the strut finger 72 to forceably push the  
9 pintle 60 away from the valve seat 64.

10

11 The inventive concepts represented by FIGS. 10A and  
12 10B apply the concepts of automatic flow regulation  
13 with shape memory alloy control elements to the  
14 hydraulic control lines 42 and/or 43 in the FIG. 2  
15 embodiment. FIG. 10A represents a check valve  
16 control 80 in the hydraulic strut power line 42. A  
17 ball closure element 82 is pressure differentially  
18 biased against the valve seat 84 to block flow  
19 through the conduit 42 into the strut 38. The  
20 closure condition prevails while the shape memory  
21 alloy driver 86 is cool and contracted. When the  
22 flow control elements are sufficiently heated by  
23 excessive flow velocity, the memory alloy driver 86  
24 expands against the disengagement probe 88 to push  
25 the ball 82 off the seat 84 and allow hydraulic flow  
26 into the strut 38. Resultantly, the strut rod 41  
27 and gate plug 36 are displaced in a direction to  
28 restrict or terminate the excessive flow.

29

30 Modifications and improvements may be made to these  
31 inventive concepts without departing from the scope  
32 of the invention. The specific embodiments shown

1 and described herein are merely illustrative of the  
2 invention and should not be interpreted as limiting  
3 the scope of the invention or construction of the  
4 claims appended hereto.

1     CLAIMS

- 2
- 3     1.    A method of regulating the flow of hydrocarbon  
4           fluid from a producing zone into a production  
5           well, said method comprising the steps of:  
6           a.    providing a fluid production tube in a  
7                 wellbore having a formation fluid  
8                 production zone, said production tube  
9                 having a production flow bore therein;  
10          b.    providing an intermediate fluid flow  
11                 channel within said production tube  
12                 between said production zone and said  
13                 production flow bore;  
14          c.    providing a static flow restriction within  
15                 said intermediate channel;  
16          d.    providing a first flow aperture between  
17                 said intermediate channel and said  
18                 production flow bore downstream of said  
19                 flow restriction;  
20          e.    providing a second flow aperture between  
21                 said intermediate channel and said  
22                 production flow bore upstream of said flow  
23                 restriction; and,  
24          f.    selectively obstructing fluid flow through  
25                 either or both of said flow apertures.  
26
- 27     2.    A method as described by claim 1 wherein said  
28           flow apertures are selectively opened and  
29           closed.  
30
- 31     3.    A method as described by claim 1 wherein fluid  
32           flow through said first aperture is obstructed

1 by a selective obstruction of flow through said  
2 flow restriction.

3

4 4. A well tool for regulating the flow rate of  
5 fluid from an earth producing zone, said tool  
6 comprising:

7 a. a well fluid production tube having a  
8 production flow channel therein and a  
9 production fluid flow screen for passing  
10 fluid from said producing zone into said  
11 production flow channel;

12 b. an intermediate flow channel between said  
13 flow screen and said production flow  
14 channel;

15 c. a static flow restriction in said  
16 intermediate channel;

17 d. a first fluid flow aperture between said  
18 intermediate flow channel and said  
19 production flow channel disposed  
20 downstream of said static flow  
21 restriction;

22 e. a second fluid flow aperture between said  
23 intermediate flow channel and said  
24 production flow channel disposed upstream  
25 of said static flow restriction; and

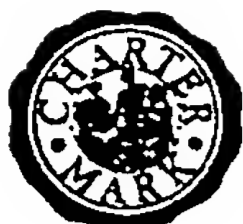
26 f. a selectively positioned flow obstruction  
27 for substantially preventing fluid flow  
28 through either or both of said flow  
29 apertures.

30

- 1     5.    A well tool as described by claim 4 wherein  
2           said selectively positioned obstruction is  
3           driven by a shape memory alloy.  
4
- 5     6.    A well tool as described by claim 4 wherein  
6           said selectively positioned obstruction is a  
7           solenoid valve operator respective to said flow  
8           apertures.  
9
- 10    7.    A well tool as described by claim 6 wherein  
11       said valve operator comprises a flow by-pass  
12       element.  
13
- 14    8.    A well tool as described by claim 7 wherein  
15       said by-pass element comprises a valve stem  
16       conduit having an open entry aperture in said  
17       intermediate flow channel and a plugged exit  
18       aperture in said production flow channel.  
19
- 20    9.    A well tool as described by claim 4 wherein  
21       said flow obstruction comprises a fluid flow  
22       gate within said intermediate flow channel for  
23       obstructing fluid flow into said flow  
24       restriction.  
25
- 26    10.   A well tool as described by claim 9 wherein  
27       fluid flow through said fluid flow gate is  
28       controlled by a selectively positioned plug.  
29
- 30    11.   A well tool as described by claim 10 wherein  
31       said selectively positioned plug also obstructs  
32       fluid flow through said second flow aperture.

- 1  
2 12. A method of regulating the flow of production  
3 fluid from a fluid producing zone into a  
4 production conduit comprising the steps of:  
5 a. providing first and second fluid flow  
6 routes for production fluid from a  
7 producing zone into a production conduit;  
8 b. providing greater resistance to flow along  
9 said second flow route relative to flow  
10 along said first flow route; and,  
11 c. providing a first selectively engaged flow  
12 obstruction along said first flow route.  
13
- 14 13. A method as described by claim 12 further  
15 providing a second selectively engaged flow  
16 obstruction along said second flow route.  
17
- 18 14. A method as described by claim 12 wherein said  
19 first and second flow routes extend from an  
20 intermediate fluid flow channel between said  
21 fluid producing zone and said production  
22 conduit.  
23
- 24 15. A method as described by claim 12 wherein said  
25 first flow obstruction is manually engaged.  
26
- 27 16. A method as described by claim 12 wherein said  
28 first flow obstruction is automatically  
29 engaged.  
30

- 1 17. A method as described by claim 12 wherein said
- 2 first flow obstruction is automatically engaged
- 3 as a function of a production fluid flow rate.



INVESTOR IN PEOPLE

Application No: GB 0201645.9  
Claims searched: 1 to 17

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Examiner: Matthew Perkins  
Date of search: 17 May 2002

## Patents Act 1977 Search Report under Section 17

### Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): E1F: FLE, FLF, FLH, FLJ, FLK, FLM

Int Cl (Ed.7): E21B

Other: Online: WPL, EPODOC, PAJ

### Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB 2361017 A (PUMP TOOLS LTD.) See abstract and figures	-
A	GB 2351748 A (MAERSK) See abstract, figures and page 2 line 23 to page 5 line 21.	-
A	GB 2314866 A (BAKER HUGHES INC.) See figures, abstract and page 4 line 6 to page 5 line 17.	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.